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Method for evaluating a scattered light signal and a scattered light detector for realizing the method

Description

The invention relates to a method for evaluating a scattered light signal generated by a scattered light receiver when detecting especially fine particles in a carrier medium.

The invention moreover relates to a scattered light detector for carrying out the above-cited method having a housing, an inlet opening and an outlet opening in said housing, between which the carrier medium flows through the housing on a flow path, having a light source which directs light to a scattered light center lying on the flow path, having a scattered light receiver for a portion of the light scattered on particles in the scattered light center, and having a scattered light signal amplifier for amplifying the scattered light signal.

Such methods and devices for evaluating a scattered light signal are known and used especially in scattered light detectors for aspiration fire alarm systems. They serve in detecting solid matter or liquid particles, whereby the carrier medium consists of a representative partial quantity of the air of a room to be monitored or the device cooling air of a device to be monitored. In the case of an aspiration fire alarm system, this representative quantity of air is actively suctioned by means of a ventilator and fed into the inlet opening of the scattered light detector. In the case of monitored devices such as EDP equipment, for example, or other similar electronic devices such as measuring, control or regulating devices, it is in principle also possible to use the internal flow of the device-cooling air itself to feed a representative partial quantity of the device-cooling air

into the inlet opening of the scattered light detector as the carrier medium. In this case, an active suctioning ventilator is then unnecessary.

A scattered light detector of the type specified at the outset typically works as follows:
While the carrier medium flows through the scattered light center on its flow path through the housing of the scattered light detector, the light of the light source traverses the scattered light center, and thus the carrier medium flowing through it and, provided it is not scattered onto particles in the carrier medium, is absorbed in a light trap opposite thereto. This is the normal and predominantly prevailing operational state. When the ray of light from the light source hits a particle, for example a smoke particle or a smoke aerosol, providing a first indication of a fire in the initial stages, this particle deflects a fraction of the light from its original direction as scattered light. This scattered light is then received by a highly photosensitive receiver, the so-called scattered light receiver, and its intensity measured by means of a subsequent evaluation circuit. An alarm is triggered when a specific light intensity threshold is exceeded.

So that such an optical system works accurately and highly sensitively, a precise adaptation to environment variables and special design features are necessary, as is the appropriate signal processing. This would entail, for example, changing the sensitivity of the detector based on the scattered light receiver's point of installation. For instance, detector sensitivity needs to be set far higher for clean rooms, in which, for example, computer chips are manufactured, than it does in offices spaces, as even the smallest quantities of dust particles or suspended particles in the air of the former needs to trigger an alarm.

Since the intensity of the light radiated by the detector's light source stands in direct correlation to the temperature, it is likewise necessary to configure temperature monitoring for the detector. It is in fact theoretically necessary, given a rising temperature, to increase the light output of the light source, for example by increasing the operational current. Apart from the high energy costs, however, this leads to a disproportionately shortened operating life, especially in the case of laser diodes. Even if the maximum operational current of an LED is not reached, operation at the maximum upper current limit shortens its life immensely. Generally speaking, configuring a highly-sensitive optical scattered light detector requires precise and adapted signal processing.

Known from the prior art in this respect is printed publication EP 0 733 894 B1 which relates to adapting the temperature of a photoelectric sensor for detecting fine particles in the air such as, for example, smoke or dust. This detector thereby has a light source and a light-receiving means which produces a sensor output upon detecting a scattering of light, that being caused by the presence of fine particles in the light radiated from the light source. The detector thereby has a control means which controls the quantity of light emitted from the light source based on a reference temperature value. The light source is thereby pulsed switched. If its temperature exceeds a specific threshold, the control means changes the interval between the individual light pulses. This enables an intensified cooling of the light source. This control loop is continued until the highest threshold is exceeded, upon which an alarm signal is then triggered, since the cause can be attributed to either a malfunctioning of the detector or the rise in temperature being due to the rise in the ambient temperature in consequence of a fire.

The disadvantage to this device, however, is that increasing the distance between the respective light pulses increases the detector's dead area, at the expense of accuracy. While this device does essentially solve the problem of dependency between temperature and light output of the light source, it indicates no possibility of counteracting the change in detector sensitivity, of calibrating the detector, or evaluating the received scattered light signal according to given specifications.

Calibrating a conventional scattered light detector is customarily done with a reference signal. To properly design, test or demonstrate fire alarm systems, it is known to conduct smoke tests using a procedure which produces smoke aerosols, wherein a test sample is pyrolized by heating. Among other things, these tests thereby serve in determining where the detectors should be arranged within an electronic system or within a room. In order to thereby make a test as realistic as possible, methods for producing smoke aerosols are used, with the help of which a reference value can be created for the smoke in order to test and/or calibrate the smoke detectors to same.

The German DE 4 329 847 C1 printed patent describes a method for producing smoke aerosols to properly design, test or demonstrate the effectiveness of fire alarm systems as well as a pyrolysis device with which to carry out this method. In the procedure, a test sample, for example an electrical cable or other such similar object, is kept at a constant or virtually constant temperature for a defined interval of time. The device and this associated method

thereby work in the so-called pyrolysis phase, in which low-power and invisible smoke aerosols are released. The detection range of modern early warning fire systems lies within this first phase of a developing fire. Depending upon the requirements for detection accuracy, it must also be possible, among other things, to then adapt the scattered light detector to this reference signal.

Based on the points specified above, the present invention addresses the task of further developing a method for evaluating a scattered light signal to be more effective, more versatile and more exact. The invention furthermore addresses the task of providing a scattered light detector to carry out the above-cited method, its mode of functioning being more precise, more versatile, less prone to errors and less expensive than that of the scattered light detectors known in the art.

This task is solved by the method in accordance with claim 1 and by the device in accordance with claim 12 respectively. In particular, this task is thus solved by a method for evaluating a scattered light signal which is produced by a scattered light receiver upon detecting especially fine particles in a carrier medium, whereby the scattered light signal selectively or in random order succession cycles through a calibration step, a drift compensation step, a temperature compensation step, a sensitivity adjusting step and a filter algorithm step.

The task is in particular also solved by a scattered light detector comprising: a housing, with an inlet opening and an outlet opening in said housing, between which the carrier medium flows through said housing on a flow path; with a light source, which directs the light toward a scattered light center positioned in the flow path; with a scattered light receiver for a partial quantity of the light scattered onto particles in the scattered light center; and with a scattered light signal amplifier for amplifying the scattered light signal, whereby the scattered light amplifier is configured as an integration amplifier.

An essential aspect of the invention is that cycling through the various calibrating and compensating steps enables an exact adjustment of the scattered light signal. Depending upon the requirements of the scattered light signal detection, the accuracy and the prevailing environment variables, it is therefore possible to adapt the scattered light detector in such a manner so as to enable a precise and error-free scattered light detection.

In each individual above-cited step, the following adjustments are thereby made:

In the calibration step, the scattered light detector is calibrated with a reference signal. Among other factors, this adjustment takes the respective environmental conditions into account since a carrier medium can exhibit a different "base level of pollution" in normal operation depending upon site of installation.

In the drift compensation step, the above-cited calibration is made over a longer period of time, i.e. usually 2 to 3 days. Averaging the chamber value to a tracked chamber value, whereby the chamber value is the scattered light signal to be received by the scattered light detector when there is no smoke or smoke aerosol present in the scattered light center, thereby improves the accuracy of the scattered light detector, since its sensitivity adjustment can be made with due consideration of this average value.

The temperature compensation step serves in adapting the scattered light detector to the dependent temperature/radiated light output relationship. Allowance is made here for the fact that actual light output emitted by a source of light decreases as temperature increases and vice-versa.

The sensitivity adjusting step enables the scattered light detector to be adjusted to the necessary stages of sensitivity, as required depending upon detector area of application.

The filter algorithm step lastly enables the analysis of a scattered light signal subject to specific filter algorithms in order to ensure reliable and accurate alarm output.

Such a combining of different adapting and calibrating steps results in a detection method which is extremely precise, of versatile applicability and which additionally functions exceptionally accurate. Of course, in order to save costs, it would be conceivable to omit one or the other adapting steps, provided same would not be expressly necessary.

A method for evaluating a scattered light signal wherein the scattered light detector has an integration amplifier as the scattered light signal amplifier, in which the integration time of the

integration amplifier is set during the calibration step such that the scattered light signal corresponds to a reference signal of a reference indicator, constitutes an advantageous improvement with the method specified at the outset. Changing the integration time enables a very economical and readily automated adaptation of the scattered light detector to a reference signal. Among other things, it is also possible to make this adaptation by adjusting the drive current of the light source – so as to change the radiated luminous energy – which, however, occurs at the expense of the operating life of the light source and requires increased power. With the method according to the invention, the drive current of the light source remains constant.

Different methods can be used to change the sensitivity of a scattered light detector in accordance with the invention. One would be changing the pulse width of the light source drive current. Pulse width refers to the duration of a light pulse. Reducing the pulse width decreases the sensitivity of the scattered light detector, increasing the pulse width raises the sensitivity. The other possibility is changing the integration time of any integration amplifier provided to function as a scattered light signal amplifier. With this method as well, increasing the integration time of the integration amplifier leads to higher sensitivity and reducing the integration time leads to a scattered light detector with less responsiveness. Both methods of changing the sensitivity of a scattered light detector are very economical, forestall material damage and allow scattered light detectors to be adapted in an exemplary simple manner. It is hereby of course possible to change both the integration time as well as the pulse width incrementally or continuously. Incremental here refers to, for example, fixed increments of percentile sensitivities such that the scattered light detector works at 25%, 50%, 75% and 100% sensitivity. Setting these sensitivity stages is preferably done with switching means, e.g. a DIL switch. It is of course also possible to adjust sensitivity using a communication interface, for example by means of a PC or that of a network. This then allows the adjusting of a scattered light detector, an entire fire alarm system respectively, by means of just one control center.

Whether the method allows an incremental or a continuous adjustment of the integration time or the pulse width is a function of the monitoring system's boundary conditions. In order to ensure particularly effective and sensitive monitoring, as is necessary for example in clean rooms, scattered light detectors must issue a detection signal at the presence of even the smallest particle quantities in the air, which hence requires a very fine sensitivity adjustment. Besides for

conventional switches or communication interfaces for PC or networks, sensitivity adjustments can, of course, also be made wirelessly.

The relationship between temperature and light source emission has already been described in detail above. In the temperature compensation step, a temperature sensor arranged in the flow path of the carrier medium is hence used for the temperature compensation of the scattered light signal. This means that the temperature of the carrier medium and/or the environment is determined continuously or in pulses in order to be able to adapt the light source which emits light in the scattered light detector. Thus, should a rise in temperature to the carrier medium in the flow path be determined, a direct adjustment of the light source can be made in order to ensure a constant light emission. This temperature compensation is advantageously made by changing the pulse width of the drive current of the light source associated with the scattered light receiver. That means that with a rise in temperature of the carrier medium as detected by the temperature sensor, the pulse width of the light source's drive current is reduced, in consequence of which there is a lesser heating of the light source and thus also the carrier medium. If, instead, a decrease in temperature is determined, the pulse width of the light source's drive current can be increased, which entails a rise in temperature. Yet in all cases, the light source's drive current remains constant.

It is advantageous to filter the scattered light signal differently depending on its slope prior to comparison with preset threshold values, in particular alarm thresholds. In this way, deceptive values can be recognized, eliminated and a false alarm prevented, since only the presence of actual alarm values; i.e. values which are above a given threshold, will lead to an alarm output signal. The amount of time over which the scattered light signal exceeds a threshold value, in particular an alarm threshold, for example, is taken into consideration when doing so. Only once a fixed time interval is reached will an alarm signal then be emitted. The lowpass filtering of the input signal as soon as its slope exceeds a pre-defined threshold furthermore results in a scattered light detector device which has a very good signal-to-noise-ratio, since short, rapid deflections in the input signal, as frequently caused by air pollutants, i.e., small quantities of dust particles in the air flow to be monitored, are not recognized as alarm values.

A further possibility for attaining an improved detection algorithm and fewer false alarms with a scattered light detector is to generate a tracked chamber value. This tracked chamber value is

averaged from the chamber value of the scattered light detector over a longer period a time and is carried out during the drift compensation step. The chamber value is the scattered light signal which results when no smoke is present in the scattered light center of the scattered light detector. This scattered light signal is thereby preferably formed from both the detector's own reflection surfaces as well as due to pollutants in the air. Averaging this chamber value in the drift compensation step over several days; i.e., preferably 2 to 3, thus results in a very exact device calibration. This averaged tracked chamber value can be subtracted from the scattered light signal's operating conditions. One is thus left with a scattered light signal free of errors due to air pollutants, environmental conditions or a detector's own reflectance, etc.

To carry out the above-specified process steps, a scattered light detector is presented, having a housing with an inlet opening and an outlet opening in said housing, between which the carrier medium flows through the housing on a flow path, having a light source which directs the light to a scattered light center lying in the flow path, having a scattered light receiver for a portion of the light scattered by particles in the scattered light center, and having a scattered light signal amplifier for amplifying the scattered light signal, whereby the scattered light signal amplifier is configured as an integration amplifier. Amplifying the scattered light signal naturally has the advantage that even slight changes in the scattered light signal can also be detected, whereby configuring the scattered light signal amplifier as an integration amplifier allows adapting the scattered light detection without the need for any additional devices. With respect to the temperature compensation, the integration amplifier allows compensating for the light source's declining light output as the temperature rises in the scattered light detector by prolonging the observation periods – i.e., the integration time. This approach is not only inexpensive, but it also extends the life of the light source, since its radiated light output does not have to be generated by an increased drive current. Consequently, the use of the integration amplifier as a scattered light amplifier in a scattered light detector results in a device which works very energy-efficiently.

In order to adjust the scattered light receiver's sensitivity, the scattered light detector is preferably provided with switching means. To make switching the device as simple as possible, said switching means can, for example, be a DIL switch.

It is however also possible to configure the switching means as low-priced jumper connections. In order to increase user-friendliness and monitoring possibilities, it makes sense to provide a

communication interface, in particular to a PC or network. This allows the centralized monitoring of a plurality of scattered light detectors, their diagnostics respectively. When doing so, the given communication paths can be either wireless or wired. It therefore makes commensurate sense to provide a switch input for changing the sensitivity of the scattered light receiver.

Arranging a temperature sensor in the flow path of the carrier medium enables the temperature compensation as mentioned above. The arrangement of a flowmeter in the flow path of the carrier medium enables the flow detector to be additionally monitored. For example, it would then be possible to issue a signal upon detecting strong flow fluctuations, since they suggest a malfunctioning of the detector and/or the intake assembly. Configuring the air flow sensor and/ or the temperature sensor as thermoelectric components thereby represents an economical and optimally compact possibility of providing the scattered light detector with sensors of high precision.

Further embodiments of the invention are indicated in the subclaims.

The following will make reference to the drawings in describing an embodiment of the invention in greater detail. Shown are:

Fig. 1 a sectional side view of a first embodiment of a scattered light detector;

Fig. 2 a top plan view along the A-A line of the sectioned scattered light detector from the embodiment depicted in Fig. 1;

Fig. 3 a top plan view of a second embodiment of a sectioned scattered light detector;

Fig. 4 a top plan view of a third embodiment of a sectioned scattered light detector;

Fig. 5 an input/output signal graph of a scattered light detector;

Fig. 6 a diagram depicting the changes in pulse width for the drive current of a light source in relation to temperature.

The same reference numerals will be used in the following description for the same/equivalent components.

The three embodiments of a scattered light detector 1 as described in the following are directed to its use as a component of an aspiration fire alarm system. Thus, the carrier medium described in the claims is air. This air is suctioned in by a ventilator, as is customary in aspiration fire alarm systems. It is thereby conceivable to arrange the ventilator directly on housing 10 of scattered light detector 1 or yet also within a ventilation duct system external of scattered light detector 1. The methods and devices formulated in the claims are implemented and/or used in the following three embodiments.

Fig. 1 shows a sectional side view of a scattered light detector. Same comprises a housing 10 and a circuit board 40 connected thereto. Housing 10 hereby has an inlet opening 3 and an outlet opening 5. Ventilator housing 6 containing a ventilator (not shown) is fixed at inlet opening 3, said ventilator providing an air flow 8 to flow through detector 1 along flow path 7. In the present case, air flow 8 is produced, flowing through scattered light detector 1 from inlet opening 3 to outlet opening 5. It is of course also conceivable for the ventilator disposed in ventilator housing 6 to suction air such that an air flow 8' is created which flows in the opposite direction in scattered light detector 1. In order to avoid the incursion of external light from the outside, scattered light detector 1 exhibits light traps 30; 32 on both sides. Scattered light detector 1 is further provided with a light source 9 which directs a light cone 20 to a scattered light center 11 lying on flow path 7. Detector 1 furthermore exhibits a receiver 13 in the form of a photodiode. A screen 26 is moreover provided between photodiode 9 and scattered light receiver 13 which prevents the light radiated by light source 9 from hitting scattered light receiver 13 directly.

Fig. 2 shows the first embodiment from Fig. 1 in a sectional top plan view. The orientation to the section corresponds to the A-A intersecting line depicted in Fig. 1. Air which flows through scattered light detector 1 from inlet opening 3 to outlet opening 5 thereby passes scattered light center 11. Any fine particles present in air flow 8 thereby reflect the light emitted by light source 9, in this case an LED, onto scattered light receiver 13, which then effects a detection signal once a previously-defined threshold is exceeded. An air flow sensor 25 and a temperature sensor 23 are additionally provided in flow path 7 of scattered light detector 1. Air flow sensor 25 thereby serves in the assessing of whether a more continuous or some otherwise specific air flow 8 is flowing through scattered light detector 1. In the event of air flow fluctuations, it is for

example possible to issue a corresponding alarm signal. Temperature sensor 23 monitors the temperature in air flow 8 flowing through scattered light detector 1 along flow path 7 in order to, for example, enable temperature compensation. Temperature compensation is addressed further in Fig. 6.

Figures 3 and 4 are both sectional top plan views of further respective scattered light detectors. These two embodiments are identified as embodiments two and three. The scattered light detector depicted sectionally in each again exhibits light source 9 and receiver 13, whereby the light cone 20 of light source 9 and a receiver cone 22 of scattered light receiver 13 run crosswise (as in the first embodiment) and over a certain section on center line 58 of flow path 7. The flow channel which guides flow path 7 thereby exhibits a bending both in front of scattered light center 11 as well as behind scattered light center 11. The light traps 30 and 32 thus formed prevent, again as in the first embodiment, the intrusion of ambient light from the outside. The second embodiment in Fig. 3 moreover exhibits screens 26 and 28, which prevent the reflection of the light emitted from light source 9 directly onto scattered light receiver 13. A temperature sensor 23 and an air flow sensor 25 are likewise arranged on center line 58 of flow path 7 here in order to collect the detection-relevant calibration and monitoring data.

As in the embodiments depicted before, the third embodiment depicted in Fig. 4 of a scattered light detector also exhibits light traps 30 and 32. The center axes 18 and 14 of light source 9, receiver 13 respectively, are aligned such that they run parallel to or along center line 58 of flow path 7 for a certain segment – namely to the two bendings 30; 32 of flow path 7. In this embodiment as well, screens 26 and 28 are provided to prevent detection of false values. An air flow sensor 25 and a temperature sensor 23 are likewise arranged again in the flow channel formed near inlet opening 3. Thus, the temperature and flow rate of an air flow 8 flowing through scattered light detector 1 is checked before it reaches scattered light center 11.

The process steps as described in the present claims are used in the scattered light detectors 1 as described above. It is thereby possible for the scattered light signal received by scattered light receiver 13 to run through a calibration step, a drift compensation step, a temperature compensation step, a sensitivity adjustment step or a filter algorithm step in any order. The calibration step and drift compensation step thereby serve in adapting the respective scattered light receiver to, among other things, different carrier media flowing through the flow detector,

whereby calibration assumes an air flow 8 as given under normal conditions at its respective place of use. Obviously a scattered light detector used in office spaces must be calibrated to a different airflow 8 than a scattered light detector used in clean rooms. This is taken into consideration in the calibration and/or drift compensation step. The difference between these two steps is that in the drift compensation step, the so-called chamber value, the scattered light signal detected by scattered light receiver 13 if no smoke or similar foreign matter which could trigger an alarm in scattered light center 11 is detected, is averaged over a longer period of time, which usually means two to three days. This so-called tracked chamber value is then subtracted from the detected scattered light signal in order to calibrate scattered light detector 1. Adjusting the temperature of air flow 8 is possible in consequence of the temperature signal received from temperature sensor 23. Here, as noted at the outset, the fact that as the temperature rises, the light output emitted from light source 9 diminishes is taken into consideration. In order to now receive a detected output of scattered light detector 1 independent of temperature, the corresponding adjustment is made in the temperature compensation step. The scattered light signal detected by scattered light receiver 13 in the different embodiments is additionally filtered differently in a filter algorithm step. In order to eliminate any possible false signals, it is thereby conceivable to filter the scattered light signal based on its slope prior to comparing it to the preset thresholds which would lead to an alarm signal.

In order to ensure with all three scattered light detectors as exact and sensitive of a monitoring of air flow 8 as possible, the various different embodiments exhibit a scattered light amplifier (not shown) to amplify the scattered light signal detected by scattered light receiver 13, for example in the form of an integration amplifier. This integration amplifier thereby enables, for example by modifying the integration time, a change in the sensitivity of scattered light receiver 1. The greater the integration time selected, the more sensitive scattered light detector 1. This change can thereby be made incrementally or continuously.

Fig. 5 shows a signal input/output graph. Input signal 2 thereby corresponds to an unfiltered signal, as would be detected by scattered light receiver 13 in scattered light detector 1. Output signal 4, in contrast, corresponds to a signal which has already been modified by special filter algorithms. Note is to be made here of the four peak values A, B, C, D in input signal 2, whereby only peak value C exceeds the threshold value of "1" over a longer period of time, based on which an alarm or detection signal will be triggered. In contrast, the so-called deceptive values A,

B and D are capped by the filter algorithm and do not lead to an alarm signal. To be noted here is that while false values B and D also exceed the "1" threshold, their exceedance does not last long enough and are thus not recognized as an alarm value by the internal filter and are thus capped. An adapted filter specification can thus yield a scattered light detector which is optimally adapted to environmental and other similar conditions.

Fig. 6 represents possibilities for compensating temperature in the three flow detectors from Figures 1 to 3. Shown first in Ill. 6.1 is a diagram of the pulsed operation of light source 9. In normal operation, same exhibits a pulse phase 50 having a pulse width of, for example, three milliseconds, followed by a rest phase 52 of one second. In rest phase 52, light source 9 cools down while in pulse phase 50 it heats up, so that a consistent temperature profile can be expected in the air flow channel under normal conditions. However, should air flow sensor 25 determine a rise in temperature, it is possible, as depicted in Ill. 6.2 and 6.3, to gradually reduce the pulse width of pulse phase 50 in order to effect a lower resulting temperature for light source 9. Changing the pulse width of the light emission – this corresponds to changing the pulse width of the drive current for light source 9 – of course also effects a decrease in sensitivity, which can then be compensated accordingly in the sensitivity adjustment step or another calibration step.

Note is herewith made that all components described above alone and in any combination are claimed as being fundamental to the invention, especially the details depicted in the drawings. Modifications hereof will be familiar to a person skilled in the art.

List of Reference Numerals

1	detector
2	input signal
3	inlet opening
4	output signal
5	outlet opening
6	ventilator housing
7	flow path
8	air flow
9	light source
10	housing
11	scattered light center
13	scattered light receiver
14	center axis
17	scattered light signal amplifier
18	center axis
19	switching means
20	light cone
21	switching means
22	receiver cone
23	temperature sensor
25	air flow sensor
26	screen
28	screen
30	light trap
32	light trap
40	circuit board
50	pulse phase
52	rest phase
58	center line of flow path